3D Printing Airway Trainers

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Problem Statement

- Airway management is an integral part of keeping a patient stable in many medical environments
- While training medical practitioners with simple airway trainers has improved patient outcomes, these trainers can cost upwards of $3000, which is cost prohibitive to many possible users [1]
- The use of 3D printing from existing patient imaging to create realistic and individualized airway manikins would assist medical professionals, allowing them to practice airway management skills on lifelike models

Intubation & Airway Trainers

- Clinicians typically only have on average 15-30 seconds to secure an airway before possible onset of hypoxia and brain damage [2]
- 50% of intubations on difficult airways fail on the first attempt in emergency settings [2]
- The failure to successfully intubate a patient on the first attempt leads to a 33% increase in likelihood for patients to experience complications from lack of oxygen [2]
- Taking a preoperative MRI of a patient's airway allows for generation of a unique 3D printable render
- Patient specific airway trainers can allow clinicians to practice intubating on difficult airways
- The amount of clinician endotracheal intubation experience is directly correlated to patient outcomes [3]
- The process of 3D printing the patient's airway will reduce the chance of procedural complications during surgery by familiarizing the clinician with the difficult airway
- Other airway trainers on the market do not account for abnormal airways and only the 7-SIGMA trainers include craniofacial abnormalities [4]

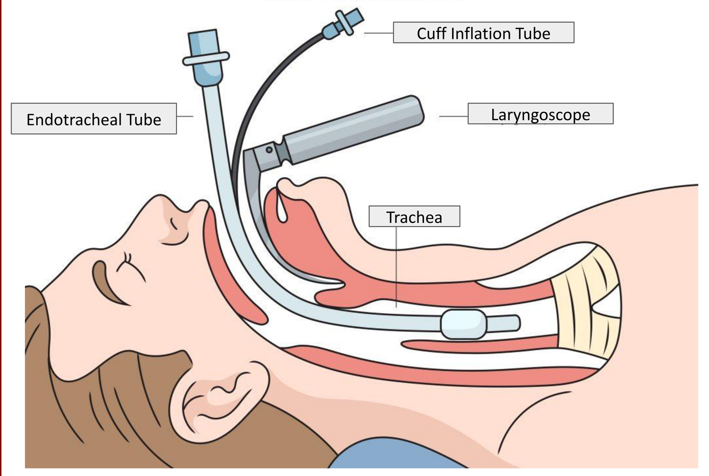

Figure 1: Tracheal Intubation [5]


Figure 2: Volunteer Airway MRI

Design Specifications

- The goal for the semester was to develop a process that can turn an MRI file into a 3D printed airway trainer
- The final print should have >90% anatomical accuracy
- The Shore hardness of the airway should be 60-91 A, but can vary depending on the selected infill of the print and material choice [6]
- The airway trainer should withstand 20,000 intubation cycles to be comparable with other trainers on the market [7]
- In order to be clinically effective, the process should be streamlined so that a printed airway can be made within 72 hours after the MRI
- Scans taken must be anonymized before being used on rendering software as to comply with the HIPAA protections on personal information [8]

Final Design

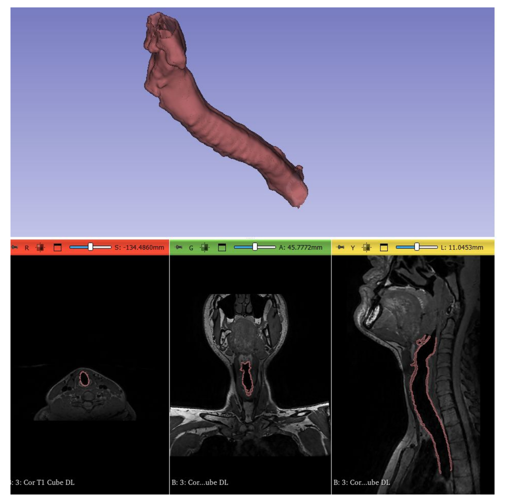
Figure 3: Segmentation

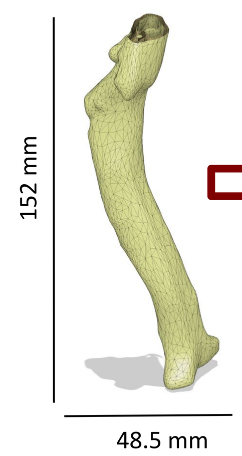

Figure 4: 3D Render

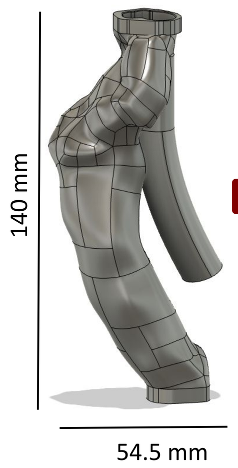

Figure 5: Solid Body

Figure 6: 3D Print

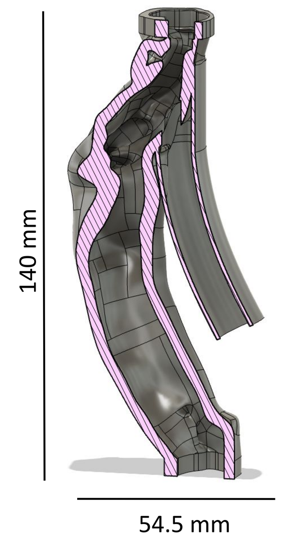

Figure 7: Solid Body Cross Section


Figure 8: Prototype Trainer

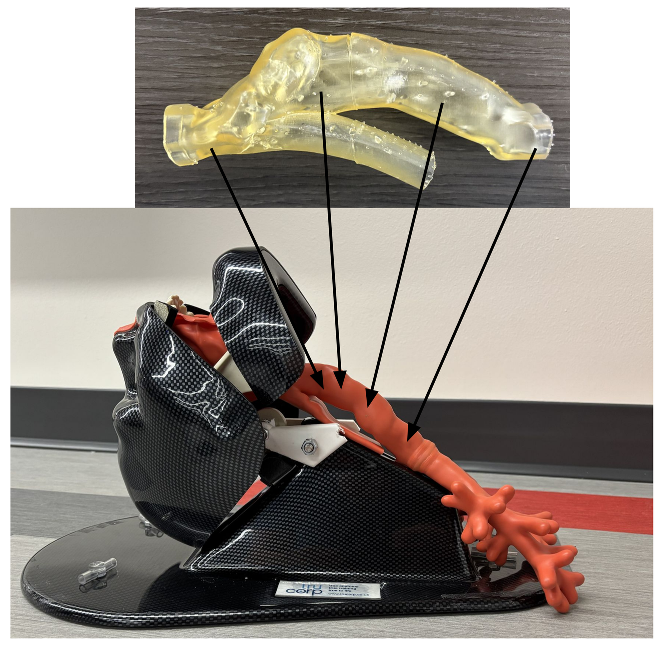
Figure 9: Hypothetical Attachment Points

Testing

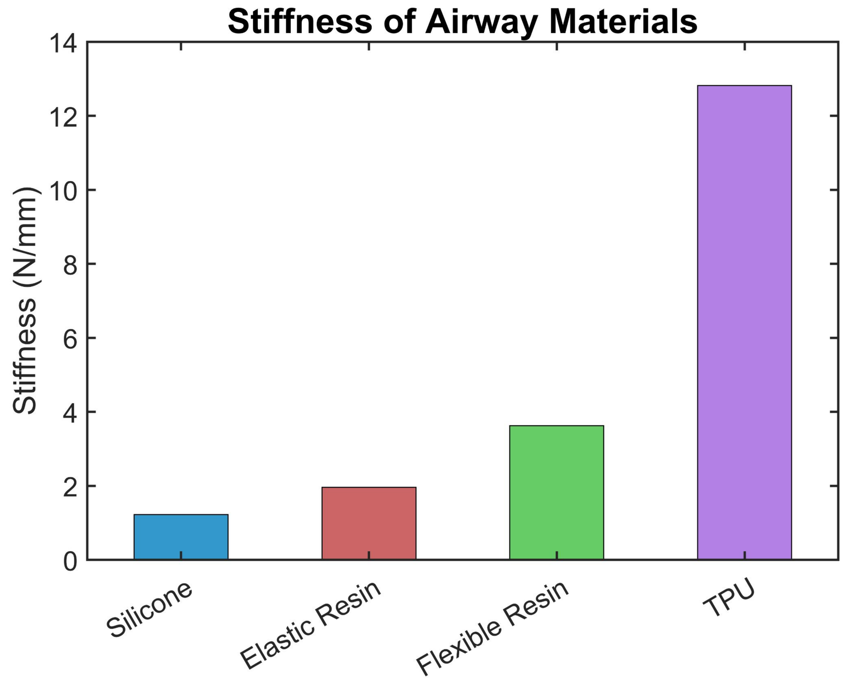

Figure 10: Stiffness of Four Materials During Compression Testing


Figure 11: Flexible Resin Before Compression


Figure 12: Flexible Resin After Compression

Durability Testing

- An airway was printed out of each material and intubated on the prototype trainer until visible damage occurred
- The silicone airway tested was made as part of the manikin

Compression Testing

- Deformation of each material was measured under a compressive load of 24.6 N, a typical load experienced during intubation [9]
- Values were converted into stiffness to compare material properties

Material	Silicone	Elastic Resin	Flexible Resin	TPU
Intubations until damaged	>50 - No Damage	4	7	>50 - No Damage

Table 1: Durability Results For All Materials During Intubation

Results & Conclusions

- **MTS Compression Testing**
  - As expected, the resin-printed airways had lower stiffnesses than TPU
  - Formlabs elastic resin most accurately replicated the stiffness of the silicone manikin
  - TPU was determined to be too stiff to be accurate as an airway material
- **Repeated Intubation Testing**
  - The TPU airway withstood 50 repetitions with slight deformity in the opening and no tearing
  - Both resin airways developed a small tear within the first 10 repetitions that continued to grow in the following few intubations
  - Tears were a result of the airway opening being too small; if the opening was wider than the laryngoscope, it likely would not tear
  - The two resin airways failure points were different, likely due to a slight malformation of the elastic airway during printing
  - None of the airways showed signs of being scratched during testing
- **Conclusions**
  - The material testing determined that ductile materials like silicone and elastic resin are more optimal choices for intubation trainers
  - Material properties under physiological conditions do not necessarily need to be replicated during intubation practice to achieve effective training

Discussion & Future Work

- **Accomplishments**
  - Created a defined process for going from MRI to 3D print
  - Printed multiple airways and came to a decision on a final material
- **Drawbacks of Current Design/Process**
  - The time between scan to print did not fall within the desired 72 hour window per design specifications
  - The Shore hardness was out of the specified range, but had tactile properties most similar to any professional airway trainer
- **Moving Forward**
  - Expand proficiency with 3D Slicer and modeling software to improve anatomical accuracy per the design specifications
  - Consider CT Scans instead of MRI
  - Begin work on building our own manikin to attach our airways
  - Explore modulation of other trainer features including tongue size, mandible position, neck angle, and integration of multiple materials

References

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